

Heating with Wood: Principles of Combustion

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This MontGuide explains how wood burns. It discusses the basic requirements for combustion and factors that can improve or hinder it. It offers a basic understanding of wood combustion that may be helpful in comparing wood stoves or operating yours more cleanly, safely and efficiently.



MontGuide

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KNOWING THE PRINCIPLES OF

combustion, particularly the combustion of wood, is important to anyone who is considering purchasing a wood stove and is evaluating design features of stoves.

Knowing combustion principles helps people decide if the claims for a stove are valid and which stove best fits their needs. In addition, understanding how wood burns help the wood stove operator burn wood more cleanly, safely and efficiently.

Combustion basics

All combustion requires three elements: fuel, an oxidizer and a source of heat. When these three elements are combined in the appropriate environment, combustion will occur. If any of the elements is removed, combustion stops.

With a wood-burning stove, wood is obviously the fuel, air is the oxidizer and the initial source of heat is usually the flame from a match.

Fuel

Wood is similar in structure to fiberglass. The fibrous part of wood that is similar to glass fibers is called cellulose. The cellulose is embedded in a material called lignin, which acts like the resin in fiberglass. Both cellulose and lignin are made by trees from simpler materials. The sun supplies the energy to make these substances

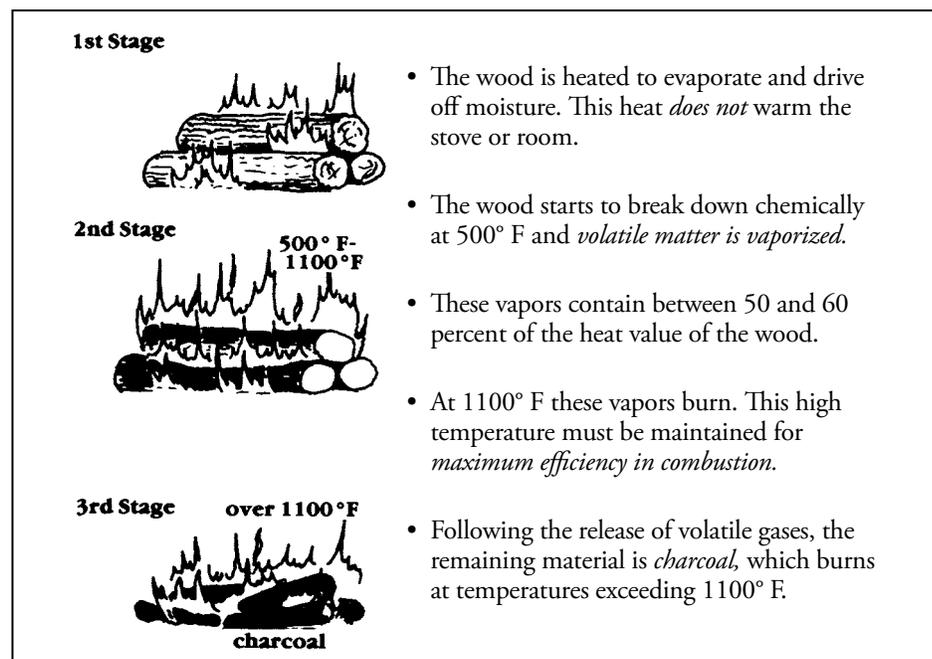


Figure 1. Stages of Wood Combustion

through photosynthesis. Photosynthetic energy stored in the wood is released during combustion. Thus, the energy released from burning wood to heat your home actually came from the sun when the wood was forming. Also contained in wood is a large amount of water, as well as minerals, oils and other compounds.

Air

Air is composed of two main gases: nitrogen and oxygen. In combustion, only oxygen is chemically active. Nitrogen is inert, but since it makes up almost 80 percent of the air, it cools down a fire by taking away heat.

Heat

The heat released from burning one part of wood or charcoal bed ignites other parts of the wood. Small pieces of burning wood are needed to ignite larger pieces.

Stages of wood combustion

Burning wood involves several processes, as Figure 1 illustrates.

Stage one combustion

The first stage of combustion is the heating and evaporating stage. Initially, heat is brought into contact with a piece

of wood in the presence of air. Heat causes several reactions.

First, it raises the temperature of an area on the wood surface to some depth into the wood. As the wood's surface temperature approaches 212 degrees Fahrenheit, the water in the wood begins to boil, then evaporates. As long as the water remains in the wood, its boiling and evaporation rob heat energy from the source, thereby keeping the wood cells from gaining more heat. Moisture must be driven off before combustion can begin, so wood with a high moisture content is hard to ignite.

Unlike moisture, volatile gases are combustible. They burn and release heat. As the wood surface temperature rises beyond 212° F to about 450° F, major gases abundant in creosote are produced: carbon dioxide, carbon monoxide and acetic and formic acids. However, the gases generated in the first stage of combustion do not ignite until the moisture evaporates and the kindling temperature is hot enough.

Stage two combustion

After moisture is driven from the wood and the heat raises the temperature of the wood above 540° F, the second stage of combustion takes place. This is the heat-producing stage. It occurs at two different temperature levels: primary and secondary combustion.

The process by which gases are released from wood and burned is

called *primary combustion*. Primary combustion begins at about 540° F, continues toward 900° F and results in the release of a large amount of energy. Primary combustion also releases large amounts of unburned combustible gases, including methane and methanol as well as more acid, water vapor and carbon dioxides.

These gases, called *secondary gases*, contain up to 60 percent of the potential heat in the wood. Their combustion is important to achieve high overall combustion efficiency. The secondary gases are not burned near the wood because of lack of oxygen (oxygen is being consumed by primary combustion) or insufficient temperature.

The conditions needed to burn secondary gases are sufficient oxygen and temperatures of at least 1100° F. The air supply is critical. Too little air will not support combustion and too much will cool the temperature to a point where combustion cannot occur.

Remember that air is about 80 percent inert gas and, when introduced into a wood stove, is below the 1100° F needed to sustain secondary combustion. The more air that mixes with the secondary gases, the greater the quantity of heat absorbed by the nitrogen, and the lower the temperature of the secondary gas-air mixture.

Secondary combustion can and does occur in wood burning stoves

but probably only during very hot fires with just the right temperature and air supply. Wood stove design features that can encourage secondary combustion include a catalytic combustor, extended circulation of gases in the stove, baffles and massive stove construction to hold heat.

Stage three combustion

During wood burning, after the gases are driven from the wood, the carbon chains of cellulose and lignin molecules remain. Carbon, or charcoal, burns a long time with a low rate of heat output. Charcoal burning is important for two reasons. Additional energy is released, which is important to overall combustion efficiency.

Also, charcoal burns at a low rate of combustion, which means that a good charcoal bed will burn a long time, allowing a fire to last the night. The fire can be rekindled by adding wood and opening the draft to supply new oxygen.

Summary

Choosing the proper wood stove helps wood burn more efficiently. However, proper operation of your stove is also critical. Understanding combustion principles and learning to manipulate the various conditions enables you to achieve maximum comfort and efficiency from a wood heating system.



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